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EP 0 337 711 B1

Description

BACKGROUND OF THE INVENTION

1) Field of the Invention

The present invention relates to a liquid crystal display device. More particularly, the present invention relates to a liquid crystal display device free from display area restrictions and able to be operated by a matrix drive.

2) Description of the Related Arts

It is known that a liquid crystal display (LCD) device can be operated under a low drive voltage at a low power consumption, and be constructed as a compact and thin device. In particular, a TN type LCD can be operated under a low voltage at a low power consumption, and thus is widely used in various fields, for example, watches and desk-type electronic calculators.

The growing popularity of word processors, personal computers, and other data processing devices has led to a demand for portable, small, and thin devices, and to this end, LCD devices are replacing the CRT (cathode ray tube) device as the display element in those machines. With the LCD device, it is possible to reproduce the image of Chinese characters on the screens of these machines, since a great number of picture elements can be used in the LCD device in comparison with the number of picture elements used in the display device used for watches and desk calculators. Also, the LCD element is operated by a matrix display drive in which picture element electrodes are connected to signal lines in an X-Y matrix form. In this type of LCD device, the picture element electrodes corresponding to the picture elements are not independent from each other, and thus when a predetermined voltage is applied to one picture element electrode, the adjacent picture element electrodes are also operated by this voltage and display an image, i.e., "cross-talk" occurs between the one picture element electrode and adjacent picture element electrode.

To eliminate this cross-talk, it is known to use a non-linear element consisting of a diode, for example, metal-insulator-metal diode (MIM) or thin film transistor (TFT) for each picture element electrode, but it is very difficult to provide and arrange a large number, for example, several thousands to several hundreds of thousands, of diodes or thin film transistors corresponding to a large number of picture elements, all of which must have uniform properties and be free from defects, and thus there is an urgent need for the development of non-linear elements which can be easily provided with a uniform quality and will allow the use of an LCD device with a large display area. In connection with the above, a new type of liquid crystal material usable for a display in a large display area has been developed through a new technology involving an NCAP (nematic curvilinear aligned phase) type liquid crystal material. With this technology, it is now possible to easily control the thickness of the liquid crystal material layer in the display device, and therefore, the NCAP type liquid crystal material can be formed as a layer having a large surface area, exhibits a very quick response, and allows the resultant display device to be given a wide angle of view without the use of a polarizer plate, and thus can be beneficially utilized to provided an LCD device having a large display surface area.

Nevertheless, the NCAP type liquid crystal material is disadvantageous in that this liquid crystal material requires a drive voltage of several tens to several hundreds of volts higher than that of TN type liquid crystal material, e.g., 5 volts or less, and therefore, a non-linear element having a higher drive voltage than that of conventional non-linear elements must be used for the NCAP type LCD device.

Also, the NCAP type liquid crystal material is disadvantageous in that the voltage-contrast property is not sufficient to produce a really sharp image, and thus when operated by a multiplex drive (simple matrix drive), the resultant display is not absolutely clear.

Further, since the NCAP type liquid crystal material needs a high drive voltage, it is difficult to utilize TFT or MIM having a low drive voltage as a non-linear element, and accordingly, it is considered by persons skilled in the art that NCAP type liquid crystal devices can not be operated by a matrix drive.

Attention is drawn to US Patent A 4 435 047 which discloses a liquid crystal display device employing a polymeric layer encapsulating tiny spheres of nematic liquid crystal.

SUMMARY OF THE INVENTION

A first object of the present invention is to provide an LCD device which contains an NCAP type liquid crystal material layer which is capable of providing a large display surface area and can be operated by a matrix drive.

Another object of the present invention is to provide an LCD device which contains an NCAP type liquid crystal material layer and can display red, green and blue colored lights at a uniform contrast thereof.

Still another object of the present invention is to provide an LCD device which contains an NCAP type liquid crystal material layer and can display

red, green, and blue colored lights at a uniform contrast thereof even when the device is operated under a low drive voltage.

The first above-mentioned object can be attained by the LCD device with the features of Claim 1 of the present invention.

The liquid crystal display device of the present invention may further comprise a plurality of red, green, and blue color filters arranged between the second base and the scanning electrode and in correspondence to the picture element electrodes.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an explanatory cross-sectional view of a conventional matrix type TN liquid crystal color display (LCCD) device;
Fig. 2 is an explanatory cross-sectional view of an embodiment of the LCD device of the present invention;
Fig. 3 shows a voltage-current curve of a varistor;
Fig. 4(A) shows an arrangement of picture element electrodes, signals lines and non-linear elements in the LCD device of the present invention;
Fig. 4(B) shows a front view of a combination of a picture element electrode with a signal line and a non-linear element;
Fig. 4(C) is a plane view of the combination shown in Fig. 4(B);
Fig. 5 shows a matrix circuit of the LCD device of the present invention;
Fig. 6(A) shows an explanatory schematic view of an NCAP type LCD device;
Fig. 6(B) shows an explanatory schematic view of an NCAP type LCD;
Fig. 6(C) shows an explanatory schematic view of a liquid crystal capsule;
Fig. 7(A) shows a transmission of light applied to a NCAP type LCD in state in which an electric field is not applied;
Fig. 7(B) shows a transmission of light through the NCAP type LCD layer in the state in which an electric field is applied;
Fig. 8 shows an explanatory cross-sectional view of another embodiment of the LCD device of the present invention;
Fig. 9 shows voltage-contrast curves of an NCAP type LCD for red, green, and blue lights;
Figs. 10(A) and 10(B), respectively, show an arrangement of picture element electrodes, nonlinear element(s) and a signal line;
Fig. 11 shows voltage-contrast curves for red, green and blue lights of an embodiment of the LCCD (liquid crystal color display) device of the present invention;
Fig. 12 shows a matrix circuit of an embodiment of the LCCD device of the present invention;
Fig. 13(A) shows a wave form of a pulse voltage applied to signal lines of an embodiment of the LCD device of the present invention;
Fig. 13(B) shows a wave form of a pulse voltage of a liquid crystal material layer of the LCD device when the voltage as shown in Fig. 13(A) is applied to the signal lines;
Fig. 14 shows a electric circuit for applying voltages to a picture element electrode and to a varistor layer;
Fig. 15(A), 15(B), and 15(C), respectively, show explanatory cross-sectional views of another embodiment of the LCCD device of the present invention;
Fig. 16(A) is an explanatory cross-sectional view of another embodiment of the LCCD device of the present invention;
Fig. 16(B) shows an arrangement of picture element electrodes, signal lines and varistor layers in the device shown in Fig. 16(A);
Fig. 17 shows voltage-contrast curves of conventional LCD devices and of embodiments of the LCD devices of the present invention;
Fig. 18 is an explanatory cross-sectional view of another embodiment of the LCD device of the present invention; and,
Fig. 19 shows voltage-contrast curves for red, green and blue lights of another embodiment of the LCCD device of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a partial cross section of a conventional matrix type TN LCCD element.

In Fig. 1, a plurality of transparent picture element electrodes l_{a1} , l_{a2} , l_{a3} ... are arranged in a predetermined pattern on the upper surface of a first transparent glass base 2a, and are covered by an orientation membrane 3a. A plurality of red, green, and blue color filters 4, 5, and 6 and a black mask 7 are arranged in a predetermined pattern on the lower surface of a second transparent glass base 2b; the color filters 4, 5 and 6 respectively corresponding to the picture element electrodes l_{a1} , l_{a2} and l_{a3}.

The color filter 4, 5 and 6 the black mask 7 are covered by a transparent scanning electrode 1b, which is then covered by an orientation membrane 3b, and a TN liquid crystal material 8 is filled in the space between the orientation membranes 3a and 3b. Then a polarizer plate 9a is arranged on the lower surface side of the first base 2a and another polarizer plate 9b is arranged on the upper surface side of the second face 2b.

The TN type liquid crystal display element as shown in Fig. 1 is very sensitive to the thickness of the liquid crystal layer 8, and thus it is difficult to use this device for a large display area. Also, the contrast of the display element is variable depending on the sharpness of the voltage-brightness contrast curve. The sharpness depends on the optical properties of the display element for each of the red, green, and blue colored light, and therefore, sometimes the display device exhibits different contrasts for the red, green and blue color lights.

Figure 2 is an explanatory cross-sectional view of an embodiment of the liquid crystal display device of the present invention.

Referring to Fig. 2, a plurality of picture element electrodes 11a are arranged in a predetermined pattern on an upper surface of a first transparent glass base 12a; a plurality of signal lines 13 for supplying electric signals to the picture element electrodes 11a are arranged adjacent to the picture element electrodes 11a on the first base 12a; a plurality of non-linear elements 14 are arranged between and connect the picture element electrodes 11a and the adjacent signal lines 13; a second transparent glass base 12b is arranged in parallel to and spaced from the first base 12a; and a transparent scanning electrode 11b is fixed to the lower surface of the second base 12b.

In the LCD device shown in Fig. 2, the space between the first base 12a and the second base 12b is filled by an NCAP type liquid crystal material 15, and the non-linear elements 14 are varistors. The varistor is usually used as a surge-absorbing element and exhibits a specific voltage-electric current property as shown in Fig. 3. Referring to Fig. 3, the varistor exhibits a high resistance under a voltage having a value less than (Va), and substantially does not allow an electric current to flow therethrough. When the voltage reaches the value (Va), however, the varistor exhibits a significantly reduced resistance and allows the electric current to flow therethrough as shown in Fig. 3. The specific value of the voltage Va is referred to as a threshold value voltage (Vth).

The varistor voltage and capacity can be easily controlled by controlling the distance between electrodes or the size of the varistor particle, and therefore, the varistor is usable in various fields; for example, as a protective material for electronic circuits and against lightning.

In the LCD device of the present invention, the NCAP type liquid crystal material, which can be operated under a relatively high drive voltage, is used in combination with non-linear elements consisting of the varistor which can control the drive voltage at a high level voltage. Therefore, in the present invention, the advantages of the NCAP type liquid crystal material can be effectively utilized, and an LCD device can effectively display various pictorial images consisting of a number of picture elements.

The varistor usable for the present invention is preferably in the form of a layer or film consisting of fine varistor particles. The layer of the fine varistor particles can be easily formed between the picture element electrodes and the adjacent signal lines by printing paste comprising, as a main component, the fine varistor particles. This printing method is advantageous in that the operation for forming the varistor layer is simple and easy, in comparison with conventional varistor layer-forming methods, and a number of non-linear elements having a uniform quality can be provided at a low cost.

When a number of fine varistor particles having a substantially uniform size and a substantially spherical shape are used, the resultant varistor layers between the picture element electrodes and the signal lines exhibit a substantially uniform threshold value voltage (Vth) and the resultant LCD device can produce a satisfactory display.

The varistor particles preferably have a size of 1 to 39 µm, more preferably 2 to 20 µm. When the varistor particles are excessively large, the resultant varistor non-linear element has an excessively large thickness, and such thick element requires a thick NCAP LC layer, and therefore, an excessively high drive voltage. When the size of the varistor particles is excessively small, the distance between the picture element electrodes and the signal lines must be shortened, and this makes it difficult to form precise gaps between the picture element electrodes and the signal lines.

Referring to Fig. 4A, a plurality of picture element electrodes 11a are separately connected to a signal line 13 through non-linear elements 14.

Referring to Figs. 4(B) and 4(C), a picture element electrode 11a and a signal line 13 fixed to a first base 12a are connected to each other through a non-linear varistor layer 14 consisting of a number of varistor particles 14a.

Referring to Fig. 5, which shows a matrix circuit of the LCD device of the present invention, a plurality of LCD elements 16 comprising picture element electrodes 11a and corresponding LC material layers (not shown) are connected to signal lines X_1, X_2, X_3 ... through varistor membranes 14 and to signal lines Y_1, Y_2, Y_3 ... crossing the signal lines X_1, X_2, X_3 .... When voltages 0, V/2 ($V/2 < Vth < V$) and 0 are applied, respectively, to the signal lines X_1, X_2 and X_3, and voltages 0, -V/2 and 0 are applied, respectively, to the signal lines Y_1, Y_2 and Y_3, the LCD element 16a connected to both signal lines X_2 and Y_2 allows an electric current to flow therethrough but none of the other liquid crystal display elements 16 allows an

electric current to flow therethrough, because the varistor layer 14 exhibits a threshold voltage (Vth) which is higher than the voltage V/2 applied thereto; i.e., the varistor layer 14 hinders the flow of electric current therethrough under a voltage of V/2 or less.

In the LCD element 16a connected to the signal lines X_2 and Y_2 , since Va < V, a voltage V-Va is applied to the element 16a, and thus undesirable cross talk between the element 16a and the other elements 16 can be prevented.

The voltage applied to the LCD element 16a connected to the signal lines X_2 and Y_2 can be maintained at a level lower than the varistor voltage, and thus the LCD element 16a can be maintained in the display state even when the voltages applied to the signal lines X_2 and Y_2 are varied, because the electric charge is held by the varistor layer.

The varistor layer or film can be produced by the following procedures.

Zinc oxide powder is molded into pellets under a pressure of 50 to 500 kg/cm^2 and sintered at a temperature of 700°C to 1300°C, the sintered pellets are pulverized to provide zinc oxide fine particles having a size of 1 to 80 µm, and the fine particles are further sintered at a temperature of 800°C to 1300°C to make the particles spherical in shape.

The sintered spherical zinc oxide particles are doped with at least one member selected from Bi_2O_3 , Co_2O_3 , MnO_2 , and Sb_2O_3 at a temperature of 700°C to 1300°C, and the resultant varistor particles preferably have a size of 0.1 to 100 µm, more preferably 1 to 20 µm. If the size of the varistor particles is excessively large, the resultant non-linear elements have an excessively large thickness, and thus requires an excessively high drive voltage. If the size of the varistor particles is excessively small, the gaps between the picture element electrodes and the signal lines must be made narrower, and it is very difficult to control the formation of such small gaps with a high accuracy.

Preferably, the varistor particles are in spherical form and have an even size, as such varistor particles will form non-linear element having a uniform threshold value voltage, and thus the resultant LCD device will display a clear picture.

The varistor layer bridges the picture element electrode and the signal line but does not completely cover the picture element electrode, and therefore, the LCD device of the present invention having the varistor layer can be used as a light transmission type device.

The resultant varistor particles are mixed with a bonding material consisting of, for example, glass particles and/or an organic binders in an amount of 5 to 200 % based on the weight of the varistor, to provide a printable varistor paste.

The organic binder is selected from evaporation-drying type binders and hardening type binders.

The evaporation-drying type binders include cellulosic materials such as methylcellulose, ethye cellulose, cellulose triacetate, polyacrylic resin, for example, poly methyl methacrylate, vinyl acetate polymer and copolymer, and polyvinyl alcohol. The binder may contain a small amount of a solvent or plasticizer.

The hardening binder may be selected from room temperature-hardening binders, for example epoxy binders (for example, DP-pure 60, made by 3M) and silicone binders (for example, TSE 352, made by Toshiba Silicone); thermal-hardening binders for example, epoxy binders (for example, JA-7434, made by 3M), an silicone binders (for example, Epoxy TSJ 3155), which are heat-hardening type binders; photohardening monomers, for example, 2-ethylhexyl acrylate and dicyclo pentenyl acrylate; photohardening prepolymers, for example, polyesteracrylate, epoxyacrylate, and mixtures of the above-mentioned substances. Preferably, the photohardening type binders containing a monomer and/or a prepolymer are used for the present invention, and further, radiation-hardening or electronic ray hardening binders are used for the present invention.

The varistor paste is applied to a first base having a plurality of picture element electrodes and signal lines, to form a bridge therebetween of a film of the paste, and the paste film is solidified, and heat-treated at a temperature of 300°C to 500°C if glass particles are used as an adhesive, to form a varistor layer.

The LCD device of the present invention contains the NCAP type liquid crystal material, which NCAP type liquid crystal material is disclosed in PCT International Publication No. WO83/01016, U.S. Patent No. 4,435,047 and "Electronic Material" No. 12, 1987, pages 67 to 70. In the NCAP type liquid crystal material, a liquid crystal material having a positive dielectric anisotropy is surrounded by a transparent surface means or matrix for effecting the natural structure of the liquid crystal material, to induce a distorted alignment thereof in the absence of an electric field and thus reduce optical transmission regardless of the polarization. The liquid crystal material is responsive to the presence of an electric field, to increase the amount of optical transmission.

In the NCAP type liquid crystal material, the above-mentioned surface means or matrix usually contains discrete amounts of the liquid crystal material dispersed therein, for example, in the form of capsules. Usually, the surface means comprises a transparent organic polymeric material having a

dielectric constant that is at least equal to the lowest dielectric constant value of the liquid crystal material. The transparent organic polymeric material may comprise a thermoplastic polymeric material for example, a polymester resin, or a thermohardening polymeric material, for example, an epoxy resin.

An embodiment of the NCAP type LCD device is shown in Figs. 6(A), 6(B) and 6(C).

Referring to Fig. 6(A), a NCAP type liquid crystal material layer 17 is arranged between an upper resinous film 18a and a lower resinous film 18b. The resinous films 18a and 18b are coated with transparent electroconductive electrode layers 19a and 19b comprising ITO.

Referring to Fig. 6(B), which shows a portion 20 of the NCAP type liquid crystal layer 17 shown in Fig. 6(A), in the portion 20 of the NCAP type liquid crystal layer 17, a number of fine particles 22 of the liquid crystal material are dispersed in a transparent matrix 23.

Referring to Fig. 6(C), in a small portion 21 of the liquid crystal material layer 17, a spherical particle 22 in a matrix 23 consists of a discrete amount of the liquid crystal material.

Figures 7(A) and 7(B) show the behaviours of the NCAP type liquid crystal material in the absence and in the presence of an electric field. In the particles, the liquid crystal material contains pleochroic dyes.

In Fig. 7(A), in the absence of an electric field, a number of liquid crystal molecules 24a are aligned along the internal surfaces of the capsules. When a visible light is introduced into the liquid crystal material particle 22 through the transparent matrix 23 in the liquid crystal material layer 17, the incident light is scattered on the outside surface of the particles 22 and in the inside of the particles 22 due to the berefringence of the liquid crystal molecule 24a, and absorbed by the pleochroic dye molecules 24b, and accordingly, the liquid crystal material layer 17 has a dark (black or opaque) appearance.

In Fig. 7(B), when an electric field is applied to the liquid crystal material layer 17, the liquid crystal molecules 24a are aligned in the direction E of the electric field. When the ordinary refractive index of the liquid crystal molecules is almost equal to that of the matrix, the light can pass straight through the liquid crystal material layer 17 without scattering, and thus the liquid crystal material layer 17 has a bright appearance. The degree of transparency of the liquid crystal material layer can be successively varied from a dark (black or opaque) condition to a bright (transparent) condition by varying the intensity of the electric field applied to the liquid crystal material layer.

The varistor layer usable for the present invention can be prepared, for example, by the following method.

Particles of ZnO are sintered at a high temperature of from 700 °C to 1300 °C and milled and screened, sintered ZnO particles preferably having a size of 1 to 30 µm, more preferably 2 to 20 µm are collected, and further, preferably, sintered at a temperature of, for example, from 800 °C to 1300 °C to give the particles a spherical shape.

The sintered ZnO particles are usually doped with at least one member selected from, for example, Bi_2O_3 , Co_2O_3 , MnO_2 , and Sb_2O_3 , preferably in an amount of 0.1 to 10 % based on the weight of the ZnO particles, and the resultant ZnO varistor particles are mixed with a bonding material.

The bonding material usually comprises a glass powder having a particle size of 0.1 to 20 µm, and/or the resinous binder such as, ethyl cellulose, butyl carbitol acetate, polyol acrylates, polyester resins, epoxy acrylates, hexanediol acrylate, and benzoin butyl ether. Usually, the glass powder is used in the amount of 5 to 200 % based on the weight of the varistor particles, and the resinous binder is preferably used in an amount of 2 to 100 % based on the weight of the varistor particles.

The varistor particle-containing paste is applied in accordance with a predetermined pattern on a base, to form a bridge between the picture element electrodes made from ITO (indium tin oxide) and the corresponding signal lines, by a screen printing method, and the printed varistor paste layers are heat-treated at a temperature of 300 °C to 500 °C to form varistor membranes. Usually, the gaps between the picture element electrodes and the corresponding signal lines are from 10 to 200 µm, for example, about 50 µm.

In the LCD device of the present invention, the first transparent base usually comprises a glass plate having a thickness of 0.5 to 2 µm, and the second transparent base usually comprises a glass plate or a transparent plastic film, for example, polyethylene terephthalate film, having a thickness of 50 to 200 µm.

The picture element electrodes and the scanning electrode usually comprise ITO (indium tin oxide, and have a thickness of 0.05 to 1 µm.

The signal lines are usually made from ITO or chromium metal and have a thickness of 0.01 to 1 µm.

The NCAP type liquid crystal material can be prepared in accordance with the method described in PCT International Publication No. WO 83/01016 and U.S. Patent No. 4,435,047.

The NCAP type liquid crystal material layer usually has a thickness of 10 to 30 µm.

In an embodiment of the LCD device of the present invention, a plurality of red, green and blue

color filters are arranged between the second base and the scanning electrode in correspondence to the picture element electrodes.

Referring to Fig. 8, a plurality of red color filters 25a, green color filters 25b, and blue color filters 25c are arranged between the second base 12b and the scanning electrode 11b in correspondence to the picture element electrodes 11a. Also, a plurality of black masks 26 are arranged between the color filters 25a, 25b, and 25c.

Generally, in an LCD device, the constant of color pictorial images depends on the sharpness of the voltage-brightness curve, and the voltage-brightness curve varies in accordance with the type and quality of the color filters, the type and amount of the pleochroic dye, the dependency of light scattering in the liquid crystal material layer, the wave length of the light, and the combination and amount (ratio) of the pleochroic dyes.

Especially, when the pleochroic dyes have absorption peaks in a short wave length band, and the two-tone ratio of the dyes is not good, the voltage-brightness curve is modified.

When a display picture is formed, the red, green, and blue lights are passed through the corresponding red, green, and blue color filters, and any difference in the voltage-brightness property of the LCD elements is the result of differences in the contrast of the colors; e.g., sometimes one color is particularly stressed.

Referring to Fig. 9, in a NCAP type LCD device, a rising part of a voltage-contrast curve of blue color light transmitted through the blue color filter shows a more gradual inclination than that of the other color filters, and accordingly, it is necessary to eliminate or reduce the difference in contrast between the red, green, and blue color pictures in the LCD device.

In an embodiment of the LCD device of the present invention, the difference in contrast is eliminated or reduced because the varistors connected to the picture element electrodes corresponding to the filters for each of the red, green, and blue colored lights exhibit a different threshold value voltage (Vth) from that for each of the other colored lights, whereby the optical properties of the display device with regard to each of the red, green, and blue colored lights is made substantially identical to those for each of the other colored lights.

Referring to Fig. 10A, in which a plurality of picture element electrodes 11_{a1} , 11_{a2} and 11_{a3} are separately connected to a signal line 13 through a plurality of varistor non-linear elements 14_{a1} , 14_{a2} and 14_{a3} , the picture element electrode 11_{a3} has a larger size than that of the other picture element electrodes 11_{a1} and 11_{a2} , and thus the leftmost end line of the electrode 11_{a3} is closer to the signal line 13 than that of the other electrode 11_{a1} and 11_{a2}. Namely, the distance d_2 between the signal line 13 and the electrode 11_{a3} is shorter than the distance d_1 between the signal line 13 and the electrode 11_{a1} or 11_{a2}.

Referring to Fig. 10(B), the picture element electrodes 11_{a1} , 11_{a2} and 11_{a3} are connected to a signal line #13 through a common varistor 14. The distance d_2 between the electrode 11_{a3} and the signal line 13 is shorter than the distance d_1 between the electrode 11_{a1} or 11_{a2} and the signal line 13.

And therefore, the threshold value voltage of the varistor 14_{a3} is differed from that of the varistors 14_{a1} and 14_{a2} , and thus the voltage-contrast property of the display device for each of the red, green, and blue colored lights becomes identical, as shown in Fig. 11. In Fig. 11, the voltage-contrast curves for the red, green, and blue colored light have a similar shape.

Referring to Fig. 12, an LCD display device has a plurality of signal lines X_1 , X_2 , X_3 ... and other signal lines Y_1 , Y_2 , Y_3 ... crossing the signal line X_1 , X_2 , X_3 ..., a plurality of LCd elements 16 having a picture element electrode 11a and corresponding to red (R), green (G) and blue (B) color filters (not shown in the drawing) connected to the signals lines X_1 , X_2 , X_3 ... through varistor membranes 14 and directly to the signal lines Y_1 , Y_2 , Y_3 ....

A pulse voltage Vs/2 is applied to the signal line X_2 , a pulse voltage -Vs/2 is applied to the signal lines Y_1 , Y_2 and Y_3 , and no voltage is applied to the signal lines X_1 and X_2. Then a pulse voltage having a wave shape shown in Fig. 13(A), is applied between the signal line X_2 and signal lines Y_1 , Y_2 and Y_3 , and as a result, a pulse voltage having a wave shape shown in Fig. 13(B) is applied to each liquid crystal color (R, G, and B) display element 16 and the display elements 16 are brought to the display state.

In Fig. 14, a voltage applied between a signal line and each LCD element 16 corresponding to the red, green or blue color filters (not shown in Fig. 14) is represented by V_{LC} , and a voltage applied to the varistor layer 14 is represented by Vth (threshold value voltage). The pulse voltage Vs to be applied to each liquid crystal color (R, G, or B) display element 16 is controlled so that it satisfies the relationship:

$$Vs/2 < Vth < Vs$$

When the pulse voltage Vs satisfies the above-mentioned relationship, in the liquid crystal color display element 16 connected to the signal lines X_1 and X_3 , the varistor layers 14 hinder the passage of an electric charge therethrough and into the LCD

elements 16, and thus substantially no voltage is applied to the display element 16 and cross talk is prevented.

Referring to Figs. 10(A), 10(B), and 12, when the distance d_2 between a signal line 13 and a picture element electrode 11_{a3} corresponding to a blue color filter (not shown in the drawings) is shorter than the distane d_1 between the signal line 13 and a picture element electrode 11_{a1} corresponding to a red color filter (not shown in the drawings) or a picture element electrode 11_{a2} corresponding to a green color filter (not shown in the drawings), the threshold value voltage Vth_R , Vth_G and Vth_B of the liquid crystal red, green, and blue colored display elements satisfy the relationship (1):

Vth_R and $Vth_G > Vth_B$.

In a liquid crystal blue color display element connected to the signal line X_2 and to the signal line Y_1 , Y_2 or Y_3 , the voltage V_{LCB} applied to the blue color display elements is:
under the application of a pulse voltage,

$V_{LCB}(P) = Vs - Vth_B$

and immediately after the application of the pulse voltage is stopped,

$V_{LCB}(O) = Vs - Vth_B$.

Also, in a red color display element and green color display element connected to the signal line X_2 and to the signal lines Y_1 , Y_2 or Y_3 , the voltages $V_{LCR}(P)$ and $V_{LCG}(P)$ applied to red and green color display elements under the application of a pulse voltage are:

$V_{LCR}(P) = Vs - Vth_R$
$V_{LCG}(P) = Vs - Vth_G$

Also, the voltages $V_{LCR}(O)$ and $V_{LCG}(O)$ applied to the red and green color display elements immediately after the pulse voltages are stopped are:

$V_{LCR}(O) = Vs - Vth_R$
$V_{LCG}(P) = Vs - Vth_G$

Accordingly, from the above-mentioned relationships, the relationships between the voltages applied to the red, green, and blue color display elements are:

$V_{LCR}(P)$ and $V_{LCG}(G) < V_{LCB}(P)$

and

$V_{CLR}(O)$ and $V_{LCG}(O) < V_{LCB}(O)$

Accordingly, the voltage applied to the blue color display element is always higher than the voltages applied to the red and green color display elements, and thus the volume of the light transmitted through the blue color display element can be controlled to a level substantially identical to, that of the light transmitted through the red and green display elements, and exhibits an improved contrast which is substantially identical to that of the red and green display elements.

In another embodiment of the LCCD device of the present invention, the distances between the picture element electrodes corresponding to the red, green, and blue color filters and the scanning electrode are adjusted to different values, to make the optical properties of the display device of each of the red, green, and blue colored lights substantially identical to those of each of the other colored lights.

For example, the distances between the picture element electrodes and the scanning electrode are controlled by providing concavities and/or convexities on at least one of the first and second bases, and forming the picture element electrodes in the concavities and/or on the convexities.

Referring to Fig. 15(A), a convexity 31 is formed on the first base 12a and a picture element electrode 11_{a1} corresponding to, for example, a blue color filter 25a, is formed on the convexity 31, with the result that the distance between the scanning electrode 11b and the picture element electrode 11_{a1} becomes shorter than that between the scanning electrode 11b and the picture element electrode 11_{a2} or 11_{a3} corresponding to the green color filter 25b or red color filter 25c.

The convexity 31 can be formed from a transparent insulating material such as glass by a physical vapour deposition (PVD) method, radio frequency (RF) sputtering method or glow discharge method.

Alternatively, concavities are formed on the surface of the first base and picture element electrodes corresponding to, for example, the red and green color filters, are formed in the concavities, with the result that the distances between the scanning electrode and the picture element electrodes become longer than that between the scanning electrode and the other picture element electrodes.

The concavity can be formed on the surface of the first base by a chemical etching method using, for example, hydrofluoric acid, or by a plasma etching method.

The concavities and convexities may be formed on the second base or both the first and second bases.

In another embodiment of the LCCD device of the present invention, the distances between the scanning electrode and the picture element electrodes corresponding to the red, green, and blue color filters are controlled by adjusting the thickness of the picture element electrodes to different values.

Referring to Fig. 15(B), the thickness of the picture element electrode 11_{a1} is larger than that of the other picture element electrodes 11_{a2} and 11_{a2} , and thus the picture element electrode 11_{a1} is closer to the scanning electrode 11b than the other picture element electrodes 11_{a2} and 11_{a3}.

In another embodiment of the LCCD device of the present invention, the distances between the scanning electrode and the picture element electrode are controlled by adjusting the thickness of the red, green, and blue color filters to different values, with the result that portions of the scanning electrode corresponding to the red, green and blue color filters are brought closer or made farther from the corresponding picture element electrodes.

Referring to Fig. 15(C), one color filter, for example, a blue color filter 25a, has a larger thickness than that of the other color filters 25b and 25c, and thus a portion 32 of the scanning electrode 11b is closer to the corresponding picture element electrode 11_{a2}.

In another embodiment of the LCCD device of the present invention, the sizes of the particles of the liquid crystal material in portions of the NCAP type liquid crystal material layer corresponding to the red, green, and blue color filters are different from each other.

The size of the particles of the liquid crystal material can be adjusted to a desired value by controlling the intensity of agitation during the procedure used for providing an emulsion in which the liquid crystal material is dispersed in the form of fine spherical particles in a matrix consisting of polyvinyl alcohol aqueous solution.

Referring to Figs. 16(A) and 16(B), a plurality of picture element electrodes 11_{a1}, 11_{a2}, and 11_{a3} respectivelycorrespond to red, green, and blue color filters 25a, 25b and 25c, and portions 15a, 15b and 15c of the NCAP type liquid crystal material layer 15, respectively, are located between the filter 25a and the electrode 11_{a1}, the filter 25b and the electrode 11_{a2}, and the filter 25c and the electrode 11_{a3}.

The picture element electrodes 11_{a1}, 11_{a2}, and 11_{a3} are connected to a signal line 13 through a varistor layer 14.

The portion 15c of the liquid crystal material layer 15 corresponding to the blue color filters 25c contains a number of particles 22a of the liquid crystal material surrounded by a transparent polymeric material. The liquid crystal particles 22a corresponding to the blue color light have a larger size than the other particles 22b in the other portions 15a and 15b of the liquid crystal material layer 15, corresponding to the red and green colored lights, and this is advantageous in that the voltage-contrast properties of the LCCD device for the red, green and blue color lights become substantially identical.

The portions 15a, 15b, and 15c of the NCAP type liquid crystal material layer 15 are formed by separately screen-printing three different printing pastes containing the liquid crystal material in the form of particles having a desired size and uniformly dispersed in a polyvinyl alcohol solution, and then solidifying the polymeric material in the printed layers.

As mentioned hereinbefore, a conventional NCAP type LCD device exhibits a poor dependency of contrast on voltage, i.e., it is very difficult to provide an NCAP type LCD device capable of exhibiting a high contrast under a low voltage. An NCAP type LCD device capable of operating under a low voltage exhibits a poor contrast as indicated by curve a in Figure 17, and another NCAP type LCD device capable of exhibiting a high contrast must be operated under a high drive voltage, as indicated by curve c in Fig. 17. In view of curve c in Fig. 17, a clear matrix display by the conventional NCAP type LCD device can be obtained only under a very high voltage. Namely, even if non-linear elements are used for the LCD elements, and if a contrast of 50:1 is required, the drive voltage, which is a sum of a voltage to be applied to the liquid crystal material layer and a voltage to be applied to the non-linear element, is about twice the voltage (about 80 volts) applied to the liquid crystal material layer (about 160 volts), and accordingly, drive circuits for the NCAP type LCD device must exhibit a high voltage resistance. Also, under the high voltage, the deterioration of the non-linear elements and the liquid crystal material is accelerated.

The above-mentioned disadvantages are eliminated or reduced by providing still another embodiment of the LCD device of the present invention, in which two display devices as described above are reversely superimposed one on the other.

That is, the embodiment of the LCCD device of the present invention comprises: a first transparent base; a plurality of picture element electrodes arranged on the first base; a plurality of signal lines for supplying electric signals to the picture element electrodes, arranged adjacent to the picture element electrodes on the first base; a plurality of non-linear elements through which the picture element electrodes are connected to the adjacent signal lines; a second transparent base arranged in parallel to and spaced from the first base; a plural-

ity of scanning electrodes arranged on a surface of the second base, and facing and spaced from the picture element electrodes; a liquid crystal material layer located between the picture element electrodes and the scanning electrodes; a third transparent base arranged close to and in parallel to the second base; a plurality of additional scanning electrodes arranged on a surface of the third base opposite to the second base; a fourth transparent base arranged in parallel to and spaced from the additional scanning electrodes a plurality of additional picture element electrodes arranged on the fourth base and facing the additional scanning electrodes a plurality of additional signal lines, for supplying electric signals to the additional picture element electrodes, located on the fourth base; a plurality of additional non-linear elements through which the additional picture element electrodes are connected to the additional signal lines; and an additional liquid crystal material layer located between the additional element electrodes and the additional scanning electrodes.

Each of the non-linear elements and the additional non-linear elements is a varistor, and the liquid crystal material in each of the liquid crystal material layer and the additional liquid crystal material layer may be in a nematic curvilinear aligned phase (NCAP).

In a further embodiment of the LCD element of the present invention, the above-mentioned device further comprises a plurality of red, green, and blue color filters interposed between the second and third bases.

Referring to Fig. 18, the LCCD device is composed of a lower unit 35, an upper unit 36 and a plurality of red, green, and blue color filters 25a, 25b, and 25c arranged between the lower and upper units 35 and 36.

The lower unit 35 has the same constitution as the LCD device indicated in Fig. 2, but the upper unit 36 has a reverse constitution to the device of Fig. 2. Namely, in the upper unit 36 a third transparent base 12d is arranged close to and in parallel to the second base 12b, so that the red, green and blue color filters are interposed between the second and third bases 12b and 12d; additional scanning electrodes 11d is arranged on the surface of th third base 12d opposite to the surface on which the color filters are arranged; a fourth transparent base 12c is arranged in parallel to and spaced from the additional scanning electrode 11d; a plurality of additional picture element electrodes 11c are arranged on the fourth base 12c and face the additional scanning electrodes 11d; a plurality of additional signal lines 13a for supplying electric signals to the additional picture element electrodes 11c are arranged on the fourth base 12c; a plurality of additional non-linear elements are arranged between and connect the picture element electrodes 11c and the signal lines 13a; and an additional liquid crystal material layer 33 is formed between the additional picture element electrodes 11c and the additional scanning electrode 11d.

Each of the non-linear elements 14 and additional non-linear elements 14a comprises a varistor layer. Also, each liquid crystal material in both of the liquid crystal material layer 15 and the additional liquid crystal material layer 33 may be in an NCAP state.

In the device shown in Fig. 18, when the contrast of display portions to non-display portions in the lower and upper units 35 and 36 is X:1 and Y:1, respectively, under a predetermined voltage applied between the picture element electrodes and the scanning electrode, the contrast of the display device consisting of the lower unit 35 and the upper unit 36 is about XY:1. Namely, the combination of the lower unit 35 with the upper unit 36 significantly increases the contrast of the display device.

EXAMPLES

The present invention will be further explained by way of specific examples, which are representative and in no way restrict the scope of the present invention.

Example 1

A zinc oxide (ZnO) powder was molded into pellets under a pressure of 400 kg/cm^2, the resultant pellets were sintered at a temperature of 1200°C in an electric furnace, the sintered pellets were pulverized and screened to provide fine zinc oxide particles having a size of from 3 to 8µm, and the zinc oxide particles were made spherical by a further sintering at a temperature of 1250°C. The resultant spherical zinc oxide particles in an amount of 100 parts by weight were mixed with 1 parts by weight of Bi_2O_3, Co_2O_3, MnO_2, and Sb_2O_3 the resultant mixture was sintered at a temperature of 1150°C, the sintered mixture was screened to provide varistor particles having a size of from 3 to 8 µm, and the varistor particles in an amount of 100 parts by weight were mixed with 30 parts by weight of glass particles having a size of 0.1 µm to 20 µm, 10 parts by weight of a binder consisting of polyvinylacetate resin and 100 parts by weight of butylcarbitol to provide a printable paste.

A plurality of picture element electrodes consisting of ITO and a plurality of signal lines consisting of ITO were formed on a first base consisting of a glass plate, in accordance with a predetermined pattern, and the gaps between the picture element

electrodes and the signal lines were about 50 µm. The printed paste was printed on the base by a screen printing method, to form a bridge between the electrodes and the signal lines, and heat treated at a temperature of 450°C to provide a plurality of varistor layers connecting the electrodes to the signal lines.

Separately, 100 parts by weight of polyvinyl alcohol were dissolved in 900 parts by weight of water, 300 parts by weight of a liquid crystal mixture consisting of mainly cyano biphenyls were mixed with 10 parts by weight of a black dye consisting of azo type pleochroic dyes, and the polyvinyl alcohol solution was mixed with the liquid crystal material to provide an emulsion in which the liquid crystal material was dispersed in a fine spherical particle form in the polyvinyl alcohol solution.

The resultant emulsion was applied to the above-mentioned first glass base with a doctor blade, to form a emulsion layer having a thickness of 10 µm, and separately, scanning electrodes consisting of ITO were formed in accordance with a predetermined pattern on a second glass plate. Then the above-mentioned emulsion was applied to the second base with a doctor blade to form a layer of the emulsion having a thickness of 10 µm.

The first base and the second base were then superimposed one on the other in accordance with a predetermined positioning arrangement, so that the emulsion layers on the first and second bases were incorporated into each other to form an NCAP type liquid crystal material layer, and the edges of the resultant devices were sealed with an adhesive.

The resultant device was operated by connecting a drive circuit to the scanning electrodes and the signal lines under a voltage of ±100 V by a multiplex drive (1/400 duty), and the device exhibited a contrast of 30:1 or more.

The resultant LCD device exhibited a satisfactory contrast.

Example 2

The same procedures as those described in Example 1 were carried out except that 100 parts by weight of the ZnO varistor particles were mixed with 15 parts by weight of ethyl cellulose and 115 parts by weight of butylcarbitol acetate to provide a varistor paste, and the second base consisted of a polyethylene terephthalate film.

The resultant LCD device exhibited a satisfactory contrast.

Example 3

The same procedures as in Example 1 were carried out with the following exceptions.

The varistor paste was prepared by mixing 150 parts by weight of the ZnO varistor particles, and 35 parts by weight of a photohardening resinous composition consisting of 11.8% by weight of a polyol acrylate, 35.3% by weight of a polyester resin, 23.5% by weight of an epoxyacrylate, 20% by weight of 1,6-hexanediol acrylate, and 5% by weight of benzoinbutylether.

The first and second bases consisted of a polyethylene terephthalate resin.

The paste film applied to the first base was hardened by radiating ultraviolet rays.

The resultant LCD device exhibited a satisfactory contrast.

Example 4

The same procedures as those in Example 2 were carried out except that a plurality of red, green, and blue color filters were arranged in the manner shown in Fig. 8.

The resultant LCCD device exhibited a satisfactory contrast.

Example 5

The same procedures as those described in Example 4 were carried out, with the following exceptions.

The NCAP type liquid crystal material layer was prepared in the following manner.

A liquid crystal (trademark: E-44, made by BDH Co.) in an amount of 15 parts by weight was mixed with 0.5 parts by weight of a pleochroic dye (trademark: M676, made by Mitsuitoatsu Dye Co.) and 40 parts by weight of a 10% aqueous solution of deionized polyvinyl alcohol (trademark: KM-11, made by Nihon Gosei Kagaku Kogyo), and the mixture was divided into two portions. One portion of the mixture was emulsified by agitating the mixture at a predetermined agitating speed, and the resultant first emulsion contained fine particles of the liquid crystal material having a size of from 1 to 4 µm.

The other portion of the mixture was emulsified at a different agitating speed from that mentioned above, and the resultant particles of the liquid crystal material in the second emulsion had a size of 4 to 10 µm.

The first emulsion was applied to the location corresponding to the red and green color filters on the first and second bases, and the second emulsion was applied to the other location corresponding to the blue color filter on the first base.

The resultant liquid crystal material layer had a thickness of 15 µm, and an LCCD device as shown in Figs. 16(A) and 16(B) was obtained.

The LCCD device exhibited voltage-contrast curves R, G, and B for the red, green, and blue colored light, as indicated in Fig. 19, and the voltage-contrast curves R, G and B were substantially identical.

Example 6

A lower unit of an LCD device was prepared by fixing a transparent electrode layer on a transparent first base consisting of polyethylene terephthalate, coating the electrode layer with an NCAP type liquid crystal material layer having a thickness of 18 µm and prepared from an emulsion of a liquid crystal material consisting of 1 g of a liquid crystal (Trademark: E-44, made by BDH Co.) and 0.03 g of a black dye (trademark: M676, made by Mitsuitoatsu Dye Co.) in 1 g of by weight of polyvinylpyrrolidone and 5 ml of chloroform, and arranging a second polyethylene terephthalate base with a transparent electrode so that the transparent electrode faces that on the first base through the liquid crystal material layer, and the edges of the resultant unit were sealed by an adhesive. This unit exhibited a voltage-contrast property as shown by curve b in Fig. 17.

An upper unit was prepared in the same manner as the lower unit, and reversely superimposed on the lower unit.

The resultant composite liquid crystal display panel exhibited an improved voltage-contrast property as indicated by curve b' in Fig. 17.

Example 7

A composite LCD device having the same constitution as shown in Fig. 18 was prepared in the following manner.

A lower unit was prepared in the same manner as in Example 1, except that the varistor threshold value voltage of each varistor layer was adjusted to 30 volts, and the liquid crystal material layer was prepared in the same manner as in Example 6.

The lower unit exhibited a contrast of 8:1, when operated under an ON voltage of 60 V and an OFF voltage of 30 V by a multiplex drive (32 Hz, 1/200 duty), and no cross-talk occurred.

An upper unit was prepared in the same manner as the lower unit, reversely superimposed on the lower unit, and the edges of the resultant composite panel were sealed with an adhesive.

When the composite panel was operated in the same manner as described above, the contrast was 60:1 and the display was very clear.

Claims

1. A multiplex drive liquid crystal display device comprising:
a first and a second transparent base (12a, 12b) arranged parallel and mutually opposed;
a layer (15) of polymeric material and liquid crystal confined between said first and second transparent bases (12a, 12b), said polymeric material forming a matrix encapsulating tiny spheres of nematic liquid crystal in the curvilinear aligned phase;
a transparent first electrode arrangement deposited on the inward facing surface of said first substrate (12a);
a transparent second electrode arrangement deposited on the inward facing surface of said second substrate (12b);
characterised in that
said first electrode arrangement includes
a matrix of picture element electrodes (11a) arranged in rows and columns and
signal lines (13) arranged in rows adjacent to the corresponding rows of picture element electrodes (11a);
said second electrode arrangement is formed by scanning electrodes (11b) arranged in columns;
each picture element electrode (11a) is connected electrically via a varistor to its corresponding signal line (13); and
each varistor is formed as a layer comprising fine particles having a size of 0.1 µm to 30 µm, whereby the display device is able to be stably operated by a multiplex drive.

2. The device as claimed in claim 1, wherein the varistor layer is formed by printing a paste composed of the fine varistor particles on the first base.

3. The device as claimed in claim 1, wherein the fine varistor particles consist essentially of ZnO particles.

4. The device as claimed in claim 1, wherein the first base comprises a glass plate.

5. The device as claimed in claim 1, wherein the second base comprises a glass plate.

6. The device as claimed in claim 1, wherein the picture element electrodes comprise ITO.

7. The device as claimed in claim 1, wherein the scanning electrodes comprises ITO.

8. The device as claimed in claim 1, wherein the liquid crystal material contains a pleochroic dye.

9. The device as claimed in claim 1, which further comprises a plurality of red, green and blue color filters disposed between the second base and the plurality of scanning electrodes in locations corresponding to the plurality of picture element electrodes.

10. The device as claimed in claim 9, wherein each respective varistor connecting a respective picture element electrode proximate a respective one of the red, green and blue color filters exhibits a different threshold value voltage (Vth) from that of other varistors connecting picture element electrodes proximate the other red green and blue color filters, whereby the voltage-contrast properties of the display device for each of red, green and blue color lights becomes substantially identical to each other.

11. The device as claimed in claim 10, wherein a distance between an adjacent one of the plurality of signal lines and the picture element electrodes corresponding to a respective one of the red, green and blue color filters is different from that distance for any of the respective other color filters.

12. The device as claimed in claim 9, wherein the distances between the scanning electrodes and the picture element electrodes corresponding to the red, green and blue color filters are adjusted to different values to make the optical properties of the display devices for each of the red, green and blue colored lights substantially identical to those for the other colored lights.

13. The device as claimed in claim 12, wherein the distances between the picture element electrodes and the scanning electrode are controlled by providing concavities and/or convexities on at least one of the first and second bases, and forming the picture element electrodes at one of the concavities and convexities.

14. The device as claimed in claim 12, wherein the distance between the picture element electrodes and the scanning electrode are controlled by adjusting the thicknesses of the picture element electrodes to different values.

15. The device as claimed in claim 12, wherein the distance between the picture element electrodes and the scanning electrode are controlled by adjusting the thicknesses of the color filters to different values so the portions of the scanning electrodes corresponding to the color filters are brought closer to and farther from the corresponding picture element electrodes.

16. The device as claimed in claim 9, wherein the sizes of the particles of the liquid crystal material in portions of the nematic curvilinear aligned phase type liquid crystal material layer corresponding to the red, green and blue color filters are different.

17. The device as claimed in claim 1, which further comprises:

a third transparent base disposed proximate and parallel to the second base;

a plurality of additional scanning electrodes disposed on a surface of the third base opposing the second base;

a fourth transparent base disposed parallel to and separated from the additional scanning electrode by a predetermined spacing;

a plurality of additional picture element electrodes disposed on the fourth base and opposing the additional scanning electrodes across the predetermined distance;

a plurality of additional signal lines for supplying electric signals to the additional picture element electrodes, located on the fourth base;

an additional liquid crystal material layer disposed between the additional picture element electrodes and the additional scanning electrodes and dispersed in a matrix consisting essentially of a polymeric material; and

a plurality of additional varistors connecting the additional plurality of picture element electrodes to the adjacent additional plurality of signal lines, each one of said additional plurality of varistor formed as a layer comprising fine particles having a size of from 0.1 to 30 µm.

18. The device as claimed in claim 1, wherein the second base comprises a polyethylene terephthalate film.

19. The device as claimed in claim 17, which further comprises a plurality of red green and blue color filters interposed between the second and the third bases.

20. The device as claimed in claim 17, wherein the additional liquid crystal material is in a nematic curvilinear aligned phase (NCAP).

21. The device as claimed in claim 9, wherein the particles of the liquid crystal material in portions of the NCAP type liquid crystal material layer corresponding to the red, green and blue color filters have different sizes from each other, which are adjusted by controlling the intensity of an agitation applied to dispersion of the liquid crystal material in a polymeric matrix in the preparation of the dispersion.

Patentansprüche

1. Eine multiplexangesteuerte Flüssigkeitskristallanzeigevorrichtung, enthaltend:
eine erste und eine zweite transparente Basis (12a, 12b), die parallel und sich gegenseitig gegenüberliegend angeordnet sind;
eine Schicht (15) aus Polymermaterial und Flüssigkristall, die zwischen diesen ersten und zweiten transparenten Basen (12a, 12b) eingeschlossen ist, wobei dieses Polymermaterial eine Matrix bildet, in der sehr kleine Kugeln aus nematischem Flüssigkristall in der krummlinig orientierten Phase eingeschlossen sind;
eine erste transparente Elektrodenanordnung, die auf der nach innen gerichteten Oberfläche dieses ersten Substrates (12a) abgelagert ist, eine zweite transparente Elektrodenanordnung, die auf der nach innen gerichteten Oberfläche dieses zweiten Substrats (12b) abgelagert ist;
dadurch gekennzeichnet, daß
diese erste Elektrodenanordnung eine Matrix von Bildelementelektroden (11a), die in Reihen und Kolonnen angeordnet sind, und
Signalleitungen (13) enthält, die in Reihen benachbart zu den zugeordneten Reihen von Bildelementelektroden (11a) angeordnet sind;
daß die zweite Elektrodenanordnung durch in Kolonnen angeordnete Abtastelektroden (11b) gebildet ist,
daß jede Bildelementelektrode (11a) elektrisch über einen Varistor an ihre zugeordnete Signalleitung (13b) angeschlossen ist,
und daß jeder Varistor als eine Schicht ausgebildet ist, die Feinstpartikel mit einer Größe von 0,1 µm bis 30 µm enthält, so daß die Anzeigevorrichtung in der Lage ist, stabil durch eine Multiplexansteuerung betrieben zu werden.

2. Die Vorrichtung nach Anspruch 1, bei der die Varistorschicht durch Aufdrucken einer aus feinen Varistorpartikeln zusammengesetzten Paste auf die erste Basis gebildet ist.

3. Die Vorrichtung nach Anspruch 1, bei der die feinen Varistorpartikel im wesentlichen aus ZnO-Partikeln bestehen.

4. Die Vorrichtung nach Anspruch 1, bei der die erste Basis eine Glasplatte umfaßt.

5. Die Vorrichtung nach Anspruch 1, bei der die zweite Basis eine Glasplatte umfaßt.

6. Die Vorrichtung nach Anspruch 1, bei der die Bildelementelektroden ITO-Material umfassen.

7. Die Vorrichtung nach Anspruch 1, bei der die Abtastelektroden ITO-Material umfassen.

8. Die Vorrichtung nach Anspruch 1, bei der das Flüssigkristallmaterial einen pleochroitischen Farbstoff enthält.

9. Die Vorrichtung nach Anspruch 1, welche weiterhin eine Vielzahl von roten, grünen und blauen Farbfiltern umfaßt, die zwischen der zweiten Basis und der Vielzahl von Abtastelektroden an Stellen angeordnet sind, die der Vielzahl von Bildelementelektroden entsprechen.

10. Die Vorrichtung nach Anspruch 9, bei der jeder Varistor, der eine zugeordnete Bildelementelektrode in der Nähe jeweils eines der roten, grünen und blauen Farbfilter anschließt, eine Schwellenwertspannung (Vth) hat, die von der der anderen Varistoren unterschiedlich ist, die Bildelementpunkte in der Nähe der anderen roten, grünen und blauen Farbfilter anschließt, wodurch die Spannungskontrasteigenschaften der Anzeigevorrichtung für jede der roten, grünen und blauen Farblichtarten im wesentlichen jeweils identisch zueinander werden.

11. Die Vorrichtung nach Anspruch 10, bei der ein Abstand zwischen einer benachbarten der Vielzahl von Signalleitungen und den Lichtelementelektroden, die jeweils einem der roten, grünen und blauen Farbfiltern entspricht, sich von dem Abstand für jeden der jeweilig anderen Farbfilter unterscheidet.

12. Die Vorrichtung nach Anspruch 9, bei der die Abstände zwischen den Abtastelektroden und den Bildelementelektroden, die den roten, grünen und blauen Farbfiltern entsprechen, auf unterschiedliche Werte eingestellt sind, um die optischen Eigenschaften der Anzeigevorrichtungen für jede der roten, grünen und blauen Farblichtarten im wesentlichen identisch zu denjenigen für die anderen farbigen Lichtarten zu machen.

13. Die Vorrichtung nach Anspruch 12, bei der die Abstände zwischen den Bildelementelektroden

und den Abtastelektroden gesteuert werden durch Anbringen von Konkavitäten und/oder von Konvexitäten auf mindestens einer der ersten und zweiten Basen, und indem man die Bildelementelektroden an einer der Konkavitäten und Konvexitäten bildet.

14. Die Vorrichtung nach Anspruch 12, bei der der Abstand zwischen den Bildelementelektroden und der Abtastelektrode durch Einstellen der Dicken der Bildelementelektroden auf unterschiedliche Werte gesteuert wird.

15. Die Vorrichtung nach Anspruch 12, bei der der Abstand zwischen den Bildelementelektroden und der Abtastelektrode durch Einstellen der Dicken der Farbfilter auf unterschiedliche Werte gesteuert wird, so daß die Bereiche der Abtastelektroden, die den Farbfiltern entsprechen, den zugeordneten Bildelementelektroden näher gebracht und weiter davon entfernt werden.

16. Die Vorrichtung nach Anspruch 5, bei der die Größen der Partikel des Flüssigkristallmaterials in Bereichen der Flüssigkristallmaterialschicht vom nematischen, krummlinig orientierten Phasentyp entsprechend den roten, grünen und blauen Farbfiltern sich voneinander unterscheiden.

17. Die Vorrichtung nach Anspruch 1, welche weiterhin enthält:
eine dritte transparente Basis, die in der Nähe und parallel zu der zweiten Basis angeordnet ist;
eine Vielzahl von zusätzlichen Abtastelektroden, die auf einer Oberfläche der der zweiten Basis gegenüberliegenden dritten Basis angeordnet sind;
eine vierte transparente Basis, die parallel zur und von der zusätzlichen Abtastelektrode um einen vorgegebenen Abstand entfernt angeordnet ist;
eine Vielzahl von zusätzlichen Bildelementelektroden, die auf der vierten Basis angeordnet sind und den zusätzlichen Abtastelektroden um einen vorgegebenen Abstand gegenüberliegen;
eine Vielzahl von zusätzlichen Signalleitungen, um elektrische Signale zu den zusätzlichen Bildelementelektroden zu leiten, die auf der vierten Basis angeordnet sind;
eine zusätzliche Flüssigkristallmaterialschicht, die zwischen den zusätzlichen Bildelementelektroden und den zusätzlichen Abtastelektroden angeordnet ist, und die feinverteilt in einer Matrix ist, die im wesentlichen aus einem Polymermaterial besteht; und
eine Vielzahl von zusätzlichen Varistoren, die die zusätzliche Vielzahl von Bildelementelektroden mit der angrenzenden, zusätzlichen Vielzahl von Signalleitungen verbindet, wobei jede dieser zusätzlichen Vielzahl von Varistoren aus einer Schicht gebildet ist, die Feinstpartikel mit einer Größe von 0,1 bis 30 μm haben.

18. Die Vorrichtung nach Anspruch 1, bei der die zweite Basis einen Polyethylen-Terephthalat-Film umfaßt.

19. Die Vorrichtung nach Anspruch 17, welche weiterhin eine Vielzahl von roten, grünen und blauen Farbfiltern enthält, die zwischen den ersten und dritten Basen angeordnet sind.

20. Die Vorrichtung nach Anspruch 17, bei der das zusätzliche Flüssigkristallmaterial sich in einer nematischen krummlinig orientierten Phase (NCAP) befindet.

21. Die Vorrichtung nach Anspruch 9, bei der die Partikel des Flüssigkristallmaterials in Anteilen der NCAP-Typ-Flüssigkristallmaterialschicht entsprechend den roten, grünen und blauen Farbfiltern unterschiedliche Größen voneinander haben, die durch Steuerung der Intensität eines Umrührens eingestellt sind, welches bei der Herstellung der Dispersion auf eine Dispersion des Flüssigkristallmaterials in einer Polymermatrix ausgeübt wird.

Revendications

1. Dispositif d'affichage à cristaux liquides à commande multiplex comprenant:
une première et une seconde bases transparentes (12a, 12b) disposées parallèlement et mutuellement opposées;
une couche (15) de matériau polymère et de cristaux liquides confinée entre lesdites première et seconde bases transparentes (12a, 12b), ledit matériau polymère formant une matrice encapsulant de minuscules sphères de cristal liquide nématique dans la phase alignée curviligne;
un agencement transparent de premières électrodes déposé sur la surface dirigée vers l'intérieur dudit premier substrat (12a); un agencement transparent de secondes électrodes déposé sur la surface dirigée vers l'intérieur dudit second substrat (12b);
caractérisé en ce que
ledit agencement de premières électrodes comporte

une matrice d'électrodes (11a) d'éléments d'image disposée en rangées et colonnes et

des lignes de signaux (13) disposées en rangées adjacentes aux rangées correspondantes des électrodes (11a) d'éléments d'image; ledit agencement de secondes électrodes est formé par des électrodes de balayage (11b) disposées en colonnes; chaque électrode (11a) d'élément d'image est connectée électriquement par l'intermédiaire d'une varistance à sa ligne de signaux correspondante (13); et

chaque varistance est formée d'une couche comprenant de fines particules ayant une dimension de 0,1 µm à 30 µm, de manière que le dispositif d'affichage puisse être actionné de manière stable par une commande multiplex.

2. Dispositif selon la revendication 1, dans lequel la couche de varistance est formée en imprimant une pâte composée des fines particules de varistance sur la première base.

3. Dispositif selon la revendication 1, dans lequel les fines particules de varistance consistent essentiellement en particules de ZnO.

4. Dispositif selon la revendication 1, dans lequel la première base comporte une plaque de verre.

5. Dispositif selon la revendication 1, dans lequel la seconde base comporte une plaque de verre.

6. Dispositif selon la revendication 1, dans lequel les électrodes d'éléments d'image comportent de l'ITO.

7. Dispositif selon la revendication 1, dans lequel les électrodes de balayage comportent de l'ITO.

8. Dispositif selon la revendication 1, dans lequel le matériau à cristaux liquides contient un colorant pléochroïque.

9. Dispositif selon la revendication 1, comportant en outre une pluralité de filtres de couleur rouge, verte et bleue disposés entre la seconde base et la pluralité d'électrodes de balayage dans des emplacements correspondant à la pluralité d'électrodes d'éléments d'image.

10. Dispositif selon la revendication 9, dans lequel chaque varistance respective reliant une électrode respective d'élément d'image à proximité d'un filtre respectif de couleur rouge, verte et bleue présente une tension de valeur de seuil (Vth) différente de celle des autres varistances reliant des électrodes d'éléments d'image à proximité des autres filtres de couleur rouge, verte et bleue, de manière que les propriétés tension-contraste du dispositif d'affichage pour chaque lumière de couleur rouge, verte et bleue deviennent sensiblement identiques entre elles.

11. Dispositif selon la revendication 10, dans lequel la distance entre une ligne adjacente parmi la pluralité de lignes de signaux et les électrodes d'éléments d'image correspondant à un filtre respectif parmi les filtres de couleur rouge, verte et bleue est différente de la distance pour l'un quelconque des autres filtres respectifs.

12. Dispositif selon la revendication 9, dans lequel les distances entre les électrodes de balayage et les électrodes d'éléments d'image correspondant aux filtres de couleur rouge, verte et bleue sont réglées sur des valeurs différentes pour rendre les propriétés optiques des dispositifs d'affichage pour chacune des lumières de couleur rouge, verte et bleue sensiblement identiques à celles pour les autres lumières colorées,

13. Dispositif selon la revendication 12, dans lequel les distances entre les électrodes d'éléments d'image et l'électrode de balayage sont commandées en disposant des concavités et/ou des convexités sur au moins l'une des première et seconde bases, et en formant les électrodes d'éléments d'image sur l'une des concavités et des convexités.

14. Dispositif selon la revendication 12, dans lequel la distance entre les électrodes d'éléments d'image et l'électrode de balayage sont commandées en réglant l'épaisseur des électrodes d'éléments d'image à différentes valeurs.

15. Dispositif selon la revendication 12, dans lequel la distance entre les électrodes d'éléments d'image et l'électrode de balayage sont commandées en réglant les épaisseurs des filtres de couleur sur différentes valeurs de telle sorte que les parties des électrodes de balayage correspondant aux filtres de couleur sont rapprochées et éloignées des électrodes d'éléments d'image correspondants.

16. Dispositif selon la revendication 9, dans lequel les dimensions des particules du matériau à

cristaux liquides dans les parties de la couche de matériau à cristaux liquides de type à phase alignée curviligne nématique correspondant aux filtres de couleur rouge, verte et bleue sont différentes.

17. Dispositif selon la revendication 1, comportant en outre:

une troisième base transparente disposée à proximité de la seconde base et parallèle à celle-ci;

une pluralité d'électrodes supplémentaires de balayage disposées sur une surface de la troisième base à l'opposé de la seconde base;

une quatrième base transparente disposée parallèlement à l'électrode supplémentaire de balayage et séparée de celle-ci par un espacement prédéterminé;

une pluralité d'électrodes supplémentaires d'éléments d'image disposées sur la quatrième base et à l'opposé des électrodes supplémentaires de balayage sur la distance prédéterminée;

une pluralité de lignes de signaux supplémentaires pour appliquer des signaux électriques aux électrodes supplémentaires d'éléments d'image, situées sur la quatrième base;

une couche supplémentaire de matériau à cristaux liquides disposée entre les électrodes supplémentaires d'éléments d'image et les électrodes supplémentaires de balayage et dispersée dans une matrice consistant essentiellement en un matériau polymère; et

une pluralité de varistances supplémentaires reliant la pluralité supplémentaire d'électrodes d'éléments d'image à la pluralité supplémentaire adjacente de lignes de signaux, chacune de ladite pluralité supplémentaire de varistances formées d'une couche comprenant de fines particules ayant une dimension comprise entre 0,1 et 30 µm.

18. Dispositif selon la revendication 1, dans lequel la seconde base comporte un film de téréphtalate de polyéthylène.

19. Dispositif selon la revendication 17, comportant en outre une pluralité de filtres de couleur rouge, verte et bleue interposés entre les seconde et troisième bases.

20. Dispositif selon la revendication 17, dans lequel le matériau supplémentaire à cristaux liquides est dans une phase alignée curviligne nématique (NCAP).

21. Dispositif selon la revendication 9, dans lequel les particules du matériau à cristaux liquides dans les parties de la couche de matériau à cristaux liquides de type NCAP correspondant aux filtres de couleur rouge, verte et bleue ont des dimensions différentes les unes des autres, qui sont réglées en commandant l'intensité d'une agitation appliquée à la dispersion du matériau à cristaux liquides dans une matrice polymère lors de la préparation de la dispersion.

Fig. 1

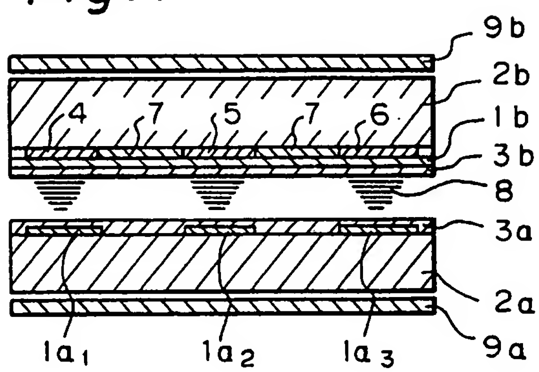


Fig. 2

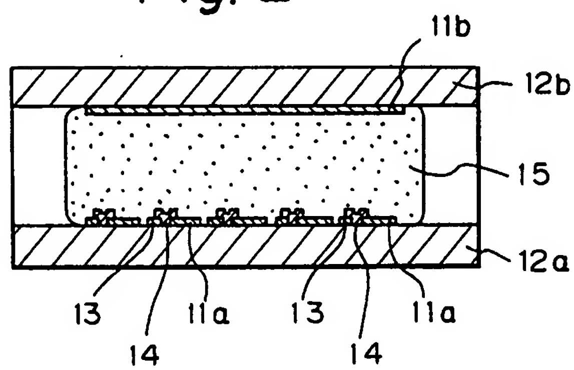


Fig. 3

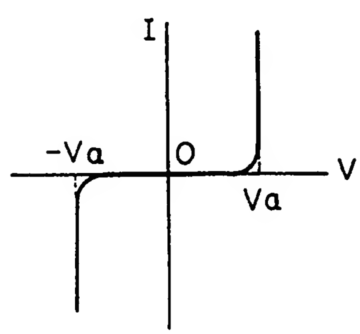


Fig. 4(A)

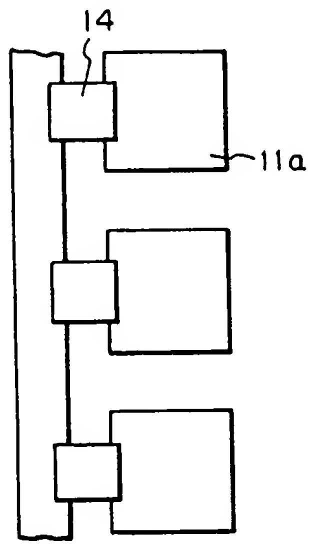


Fig. 4(B)

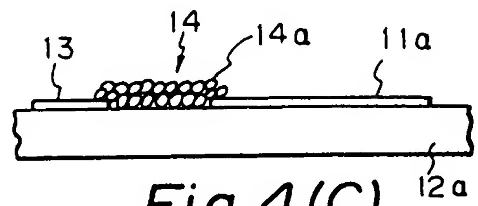


Fig. 4(C)

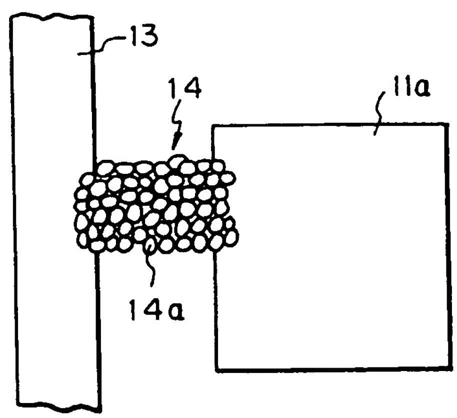


Fig. 5

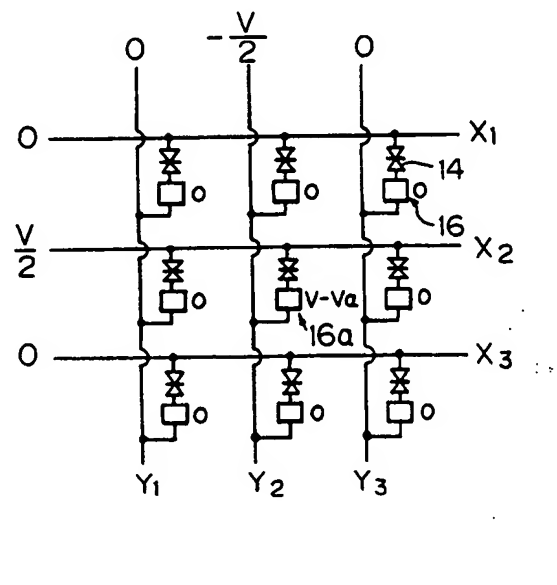


Fig. 6(A)

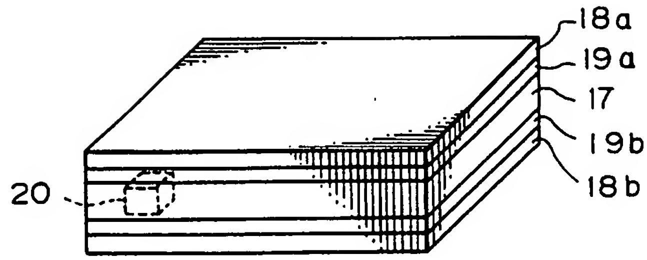


Fig. 6(B)

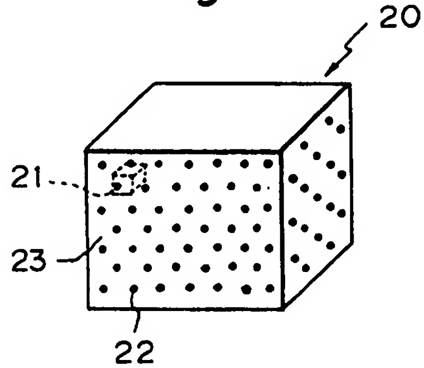


Fig. 6(C)

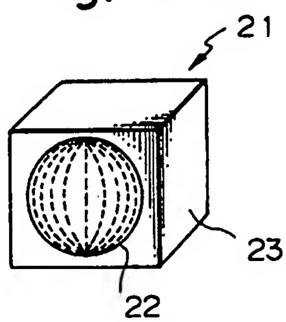


Fig. 7(A)

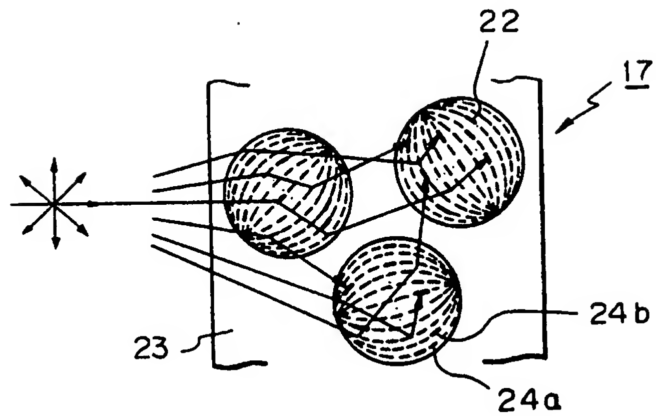


Fig. 7(B)

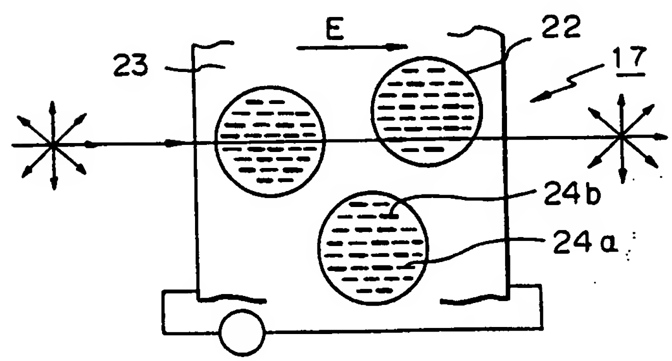


Fig. 8

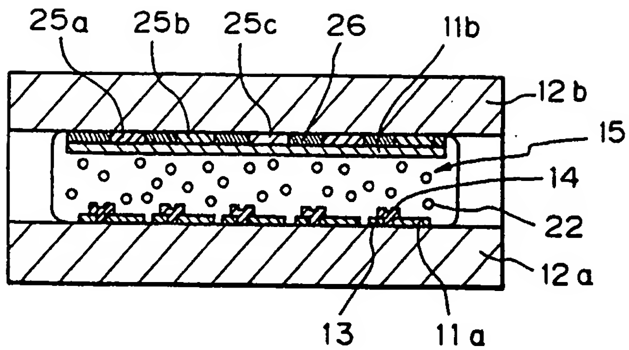

25a
25b
25c
26
11b
12b
15
14
22
12a
13
11a

Fig. 9

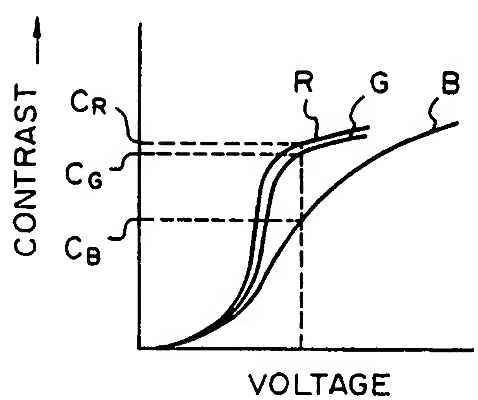

CONTRAST
CR
CG
CB
R
G
B
VOLTAGE

Fig. 10(A)

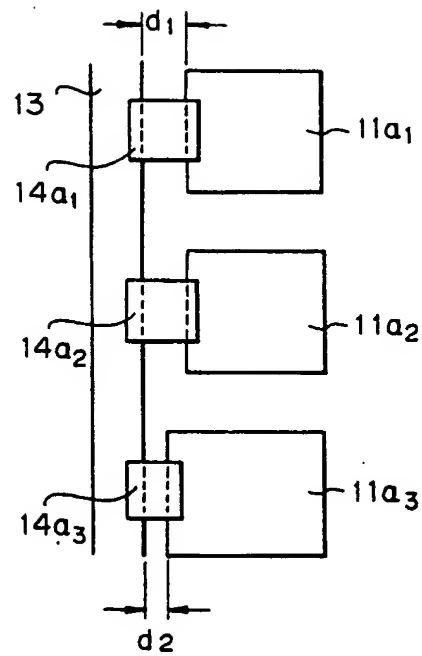


Fig. 10(B)

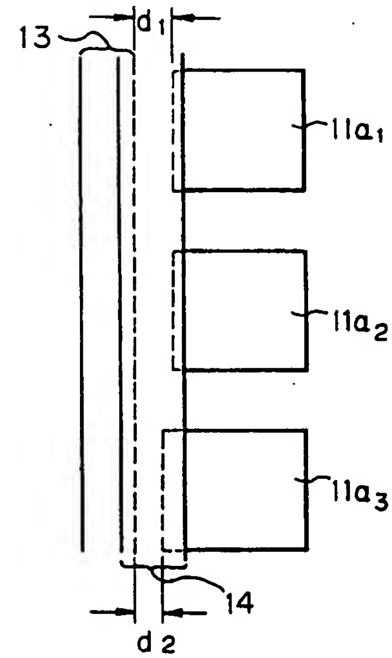


Fig. 11

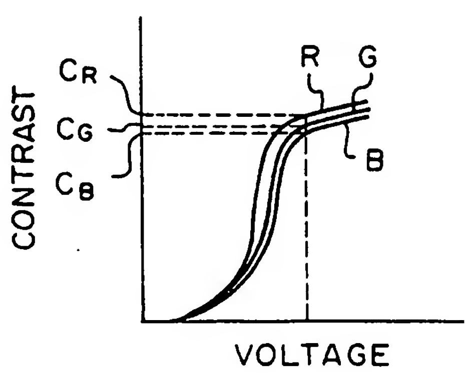


Fig. 12

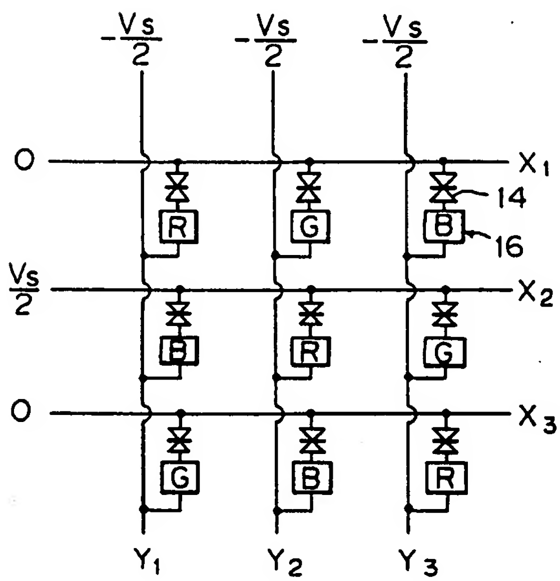


Fig. 13(A)

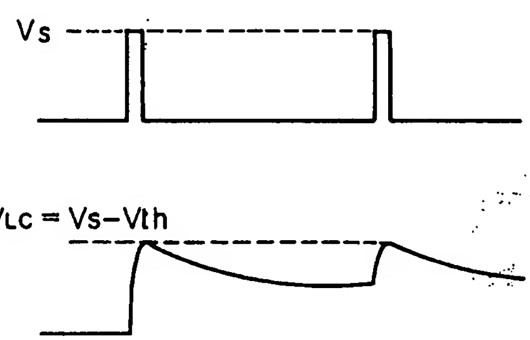


Fig. 13(B)

Fig. 14

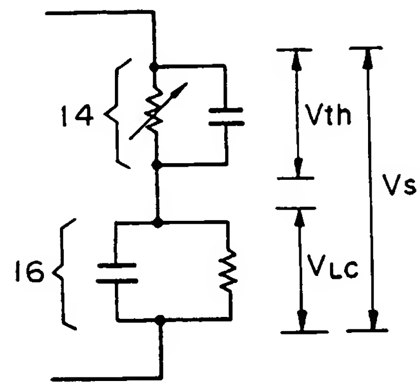


Fig. 19

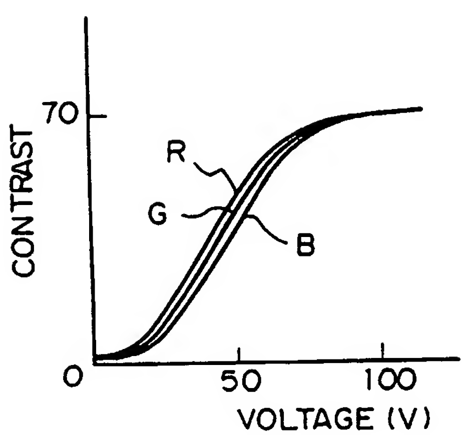


Fig. 15(A)

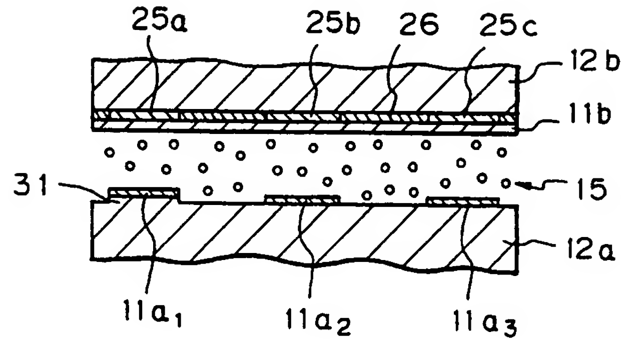


Fig. 15(B)

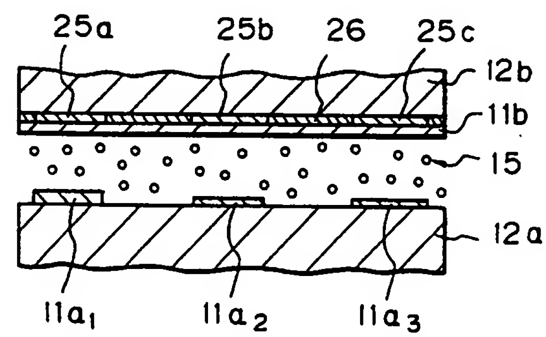


Fig. 15(C)

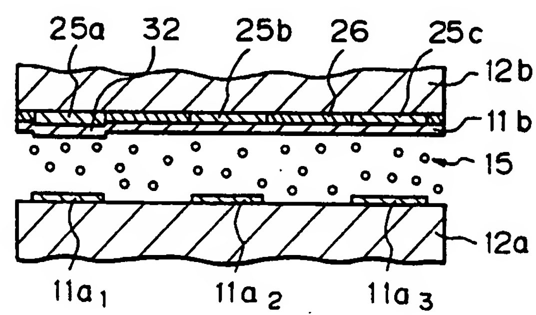


Fig. 16 (A)

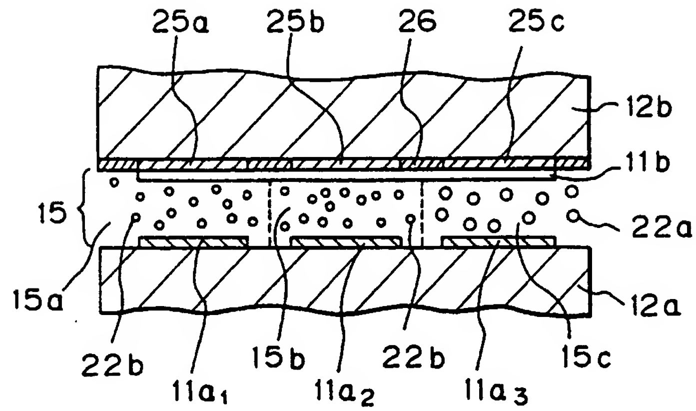


Fig. 16 (B)

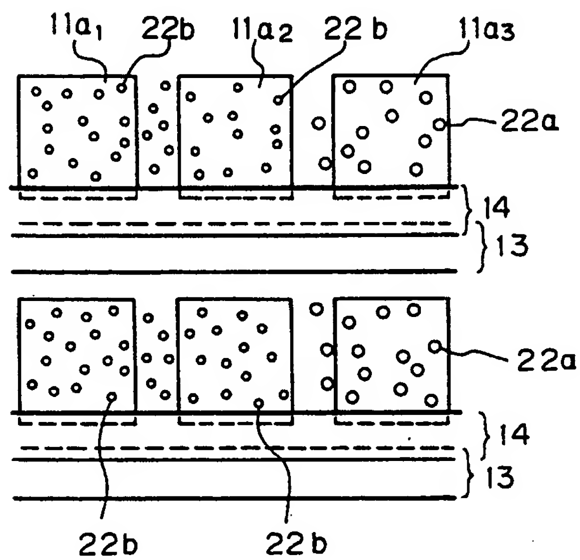


Fig. 17

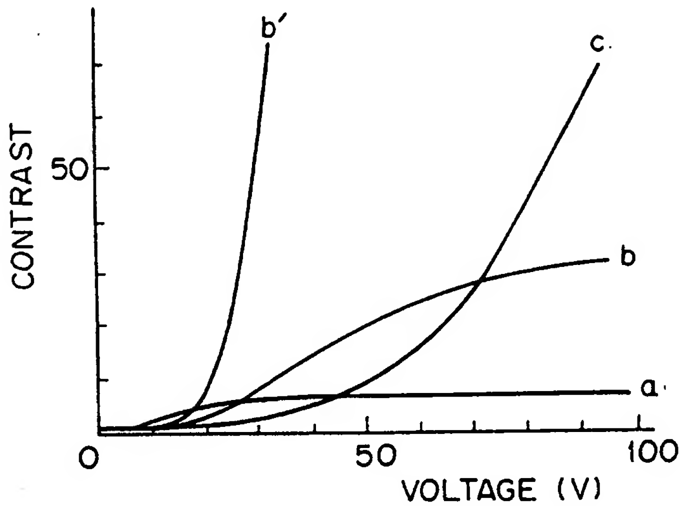
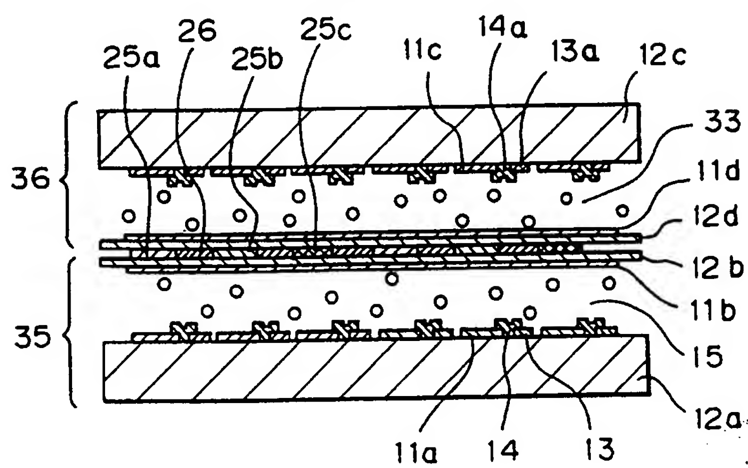

b′
c
b
a
CONTRAST
50
0
50
100
VOLTAGE (V)

Fig. 18


25a
26
25b
25c
11c
14a
13a
12c
33
11d
12d
12b
11b
15
12a
36
35
11a
14
13